Dedicated Spiral Breast Computed Tomography With a Single Photon-Counting Detector: Initial Results of the First 300 Women

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Abstract: OBJECTIVES The aim of this study was to describe our initial clinical experiences using a dedicated spiral breast computed tomography (B-CT) with a single photon-counting detector. MATERIALS AND METHODS This retrospective study was approved by the institutional review board. Examinations of 300 consecutive women undergoing B-CT were evaluated on reason of assignment for B-CT instead of mammography, detection rate of breast cancer, and quality criteria of data acquisition. Further evaluated performance indicators were the number of additional ultrasounds examinations due to unclear findings or dense breast tissue and reliability of the technical data acquisition. RESULTS Five hundred ninety-one B-CT acquisitions in 300 women were performed. The main reason for preference of B-CT over mammography was the lack of breast compression (254 of 300, 84.7%), which was desired due to personal reasons or mastodynia, whereas 10 patients (0.3%) had implants hampering mammography. One hundred two possible lesions were detected in B-CT including 4 cases of breast cancer (1.3% of all patients). Additional ultrasound was performed in 226 patients (102 due to detected lesions and 124 due to dense breast tissue). Three malignant lesions were only detected in an additional ultrasound (1% of all patients). As a quality criterion, the pectoralis muscle was included in 341 of 591 examinations, but complete assessment of breast tissue was only possible in 149, respectively 140 examinations. No movement artifacts were noted. In 99% of all women, the examination could be realized. CONCLUSIONS The dedicated B-CT provides high-quality images. It can be used as alternative particularly in those patients not otherwise willing to perform mammography because of the breast compression.

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Conclusions: The dedicated B-CT provides high-quality images. It can be used as alternative particularly in those patients not otherwise willing to perform mammography because of the breast compression.

Key Words: B-CT, mammography, breast cancer

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Breast cancer is the most often diagnosed cancer in women and the leading cause of death due to cancer in women.[1] Therefore, many countries have successfully established an organized screening program,[2,3] furthermost using mammograms to detect possible cancers as early as possible and without any socioeconomic barrier. In an organized screening program, usually only mammograms in 2 projections are performed without additional ultrasound. In opportunistic screening, an additional ultrasound can be performed if mammograms demonstrate pronounced glandular component potentially masking a cancer lesion (ACR density class C and D).[4] Mammograms are performed on each breast usually in 2 planes, cranio-caudal (CC) and medio-lateral-oblique (MLO), where the breast gets fixed between 2 polyacryl plates, and technicians are encouraged to apply a compression of at least 100 N of pressure to reduce radiation dose and increase contrast.[5] Nevertheless, many women renounce to undergo this possibly life-saving examination due to pain or discomfort.[6] In Switzerland, no systematic screening is performed throughout the country.

The dedicated spiral breast computed tomography (B-CT) using a single photon-counting detector, which was recently introduced to clinical breast imaging,[7] provides cross-sectional images of the whole breast without the requirement of breast compression and at a comparable dose to mammography.[8] In addition, the evaluation of the breast without the compression, with regular shape of the tissue and with the possibility to do multiplanar reconstructions with a high isotropic spatial resolution,[9] offers the possibility to potentially overcome the main limitation of mammography, which is the superposition of breast tissue.

The purpose of this study was to retrospectively evaluate the first clinical experiences using a dedicated spiral B-CT with a single photon-counting detector in a cohort of 300 consecutive patients.

MATERIALS AND METHODS

Study Population

This retrospective study was approved by the local ethics committee. Each patient gave a written consent. A retrospective search was performed from August 2018 to March 2019 in our PACS (Pictures Archives and Communications System) to identify the first 300 women undergoing a B-CT examination. The age range was 35 to 84 years (mean age, 56.8 ± 9.9 years). Referral information from the patient was checked to choose B-CT instead of a regular mammography.

Image Acquisition

Each breast was examined separately on a dedicated spiral B-CT system (nu:view; Advanced Breast CT GmbH, Erlangen, Germany), with the women lying in a prone position as stated in a previous article.[7] No compression was applied. Before each acquisition, the scan length was chosen by the technician at 80, 120, or 160 mm. A tube current of 25 mA was initially chosen; however, the tube current was later routinely increased to 32 mA for better resolution. A fixed x-ray tube voltage of 60 kV was used.[7] No dose modulation was possible during the examination. For image reconstructions, a Feldkamp-type filtered back-projection algorithm was used by the nu:view reconstruction software. A smooth kernel (300 μm^3) and a high-resolution option (150 $\mu m)^3$ was used for image reconstruction.

Data Analysis

Image analysis was performed on a PACS workstation equipped with a dedicated breast imaging display software (AGFA Impax 6, Mortsel, Belgium) with the possibility to obtain multiplanar reconstructions and maximum intensity projections (MIPs) for evaluation of microcalcifications and average of all description pairs (avgIP) for evaluation of the breast tissue with a slice thickness of up to 50 mm.

All examinations were read by a resident and a board-certified radiologist with experience in breast imaging (reader 1) in consensus

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TABLE 1. Description of Quality Criteria

Reader	Pectoral Muscle Covered	Whole Breast Tissue Included	Pectoral Muscle Covered and Whole Breast Tissue Included	Ring-Like Artifact	Movement Artifact
Reader 1	341 of 591	149 of 591	90 of 341	591 of 591	0
Reader 2	341 of 591	140 of 591	85 of 341	591 of 591	0

Each breast was rated separately by 2 board-certified radiologists: depiction of the pectoral muscle, including the whole breast tissue, both artifacts (ring-like artifact, movement), acquired for each breast. In total, 591 breasts of 300 women were examined (8 women had a mastectomy on 1 breast, and 1 woman had only 1 breast examined due to technical problems during the examination).

to reach a final report, and a second reading was performed by a second board-certified radiologist with experience in breast imaging (reader 2). Age of the patient, previous examination (mammography), artifacts (monolateral, bilateral, none), and reasons for additional ultrasound examinations if performed were noted. In addition, quality criteria (A, successful technical acquisition; B, depiction of the pectoralis muscle; C, inclusion of the complete glandular tissue; D, movement artifacts; and E, the previously described ring-like artifact[7]) and reasons for referral for B-CT instead of mammography were assessed. Also, findings, such as masses, architectural distortions, microcalcifications, and macrocalcifications, were noted and classified according the Breast Imaging and Reporting and Data System (BI-RADS).

RESULTS

Study Population

Seventy-eight women had a previous mammogram within 36 months (minimum-maximum, 5–160 months) before B-CT. One hundred sixty-four women declared to refuse mammography using compression including women with breast cancer diagnosed clinically and with ultrasound, 38 women declared to have chosen the B-CT due to mastodynia, 29 to avoid compression in an aftercare setting, 52 to avoid compression for checkup with a positive family history for breast cancer, 10 women with implants, and 7 to experience the newest technology.

Quality Criteria

The B-CT had to be restarted 3 times in the time interval the examinations of the 300 women were performed. Twice a system shutdown was performed at the end of the day for service. Only in one examination of a patient, the software of the system crashed due to technical issues after one breast acquisition and no additional examination was possible on the same day. This particular patient subsequently underwent conventional mammography of the not examined breast. None of the images showed any movement artifacts. In all images, a slight ring-artifact was noted; however, in no examination was image interpretation substantially hampered. In 341 of 591 B-CT examinations, the pectoralis muscle was partially depicted (see Table 1), whereas in 442 (reader 1), respectively 451 (reader 2) examinations glandular tissue was not completely depicted.

Additional Ultrasound Examinations

In 226 of 300 women, an additional ultrasound was performed by the radiologist. In 124 cases, the ultrasound was added due to dense breast tissue, and in 102 cases, the ultrasound was added to characterize a possible visible lesion in B-CT.

Breast Lesion Findings

Potential lesions were found in B-CT in 102 women (see Table 2) and were described by both readers. Fifty-seven were benign lesions (cysts or lymph nodes). Thirty-six lesions, all rated as possible fibroadenomas or complicated cysts, were rated BI-RADS 3 and will be checked in 6 months. Two possible lesions in B-CT had no correlation in ultrasound and were rated as glandular tissue. Nine lesions were visible either in B-CT and/or in ultrasound and were rated BI-RADS 4 or higher. Those lesions underwent biopsy and histological analysis (5 invasive ductal cancer, 2 invasive lobular cancer, and 2 sclerosing adenosis; Figs. 1, 2). Three of the malignant lesions were only visible in ultrasound.

Architectural distortions were found in 2 of 591 B-CT. Microcalcifications were found in 182 (reader 1), respectively 183 B-CT (reader 2) (with 10 B-CT disagreeing results), whereas macrocalcifications were found in 175 B-CTs (both readers) (Table 3).

DISCUSSION

This study describes the results of the first 300 women undergoing a B-CT examination using a dedicated spiral B-CT with a single photon-counting detector.

Most women who chose the B-CT instead of mammography stated to have chosen it because of mastodynia, fear of pain from the compression due to mammograms, or pain experienced during previous mammograms. Mastodynia and the fear of pain due to compression of the breast are a well-known limitation of persuading women to undergo mammography as a preventive examination.[10] Many women did not

TABLE 2. Description of BI-RADS Rating of the Found Lesions With Description if Detected on B-CT or US

	Detected on B-CT	Detected Only on US	Detected on B-CT and US
BI-RADS 6	2	0	2
BI-RADS 5	2	0	2
BIRADS 4	2	3	0
BI-RADS 3	25	11	25
Benign lesions	23	34	23

As benign lesions, simple cysts and lymph nodes were included; as BI-RADS 3, lesions like fibroadenomas or complex cysts were rated. Lesions rated BI-RADS 4 or higher underwent biopsy. Two possible lesions were detected on B-CT but without correlation in US and were rated as glandular tissue.

BI-RADS indicates Breast Imaging and Reporting and Data System; B-CT, breast computed tomography; US, ultrasound.

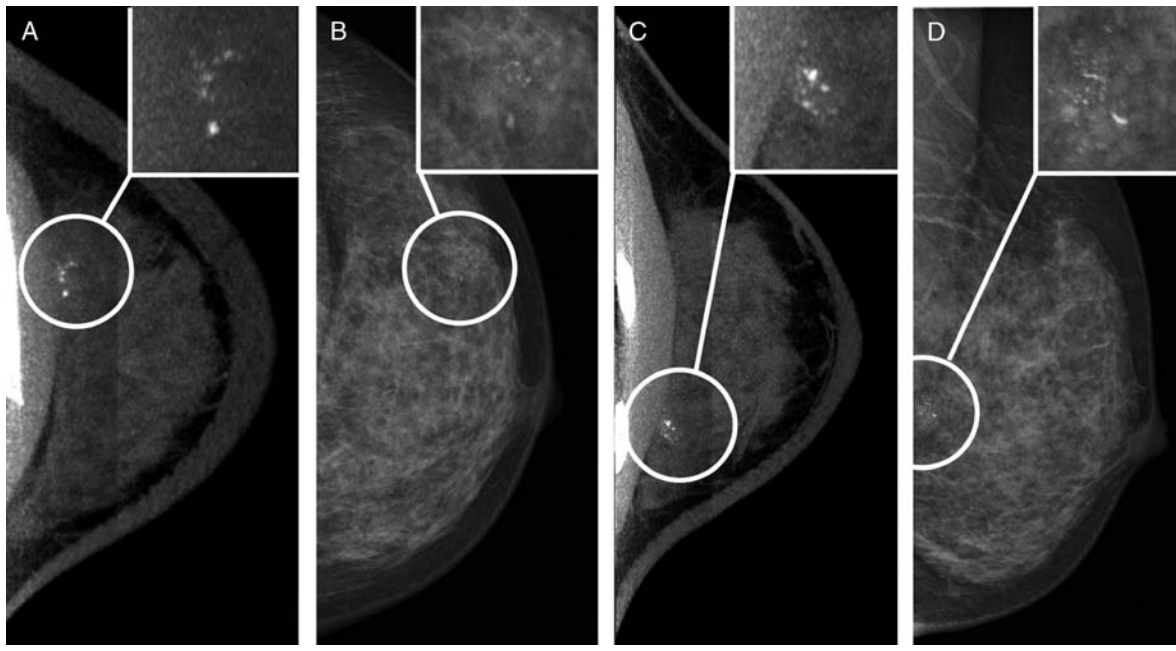

FIGURE 1. A 54-year-old patient with a normal mammography in 2017 admitted for opportunistic screening with new grouped microcalcifications in the left breast, corresponding to a sclerosing adenosis. In all pictures, the microcalcifications are marked with a white circle and amplified in the top right corner of each image. A, B-CT with axial MIP reconstruction (10 mm). B, Corresponding mammography in CC projection. C, B-CT with sagittal MIP reconstruction (10 mm). D, Corresponding mammography in MLO projection.

have a previous mammogram or it was already years ago, as they refused to endure the pain of compression again due to the examination technique to obtain a mammogram. This large cohort of women, who obviously would also renounce to participate in an organized screening program, can be motivated to undergo screening if a compression-free option is available as demonstrated in our study.

Concerning the quality of the examinations, in a previous article,[7] it was stated that, if included in the examination, the depiction of the pectoralis muscle can be used as a quality criteria to assess whether sufficient completeness of visualization of breast tissue was obtained. This is certainly true, but in most of the cases as stated in the results, still lots of examinations miss the acquisition of the whole breast tissue, also

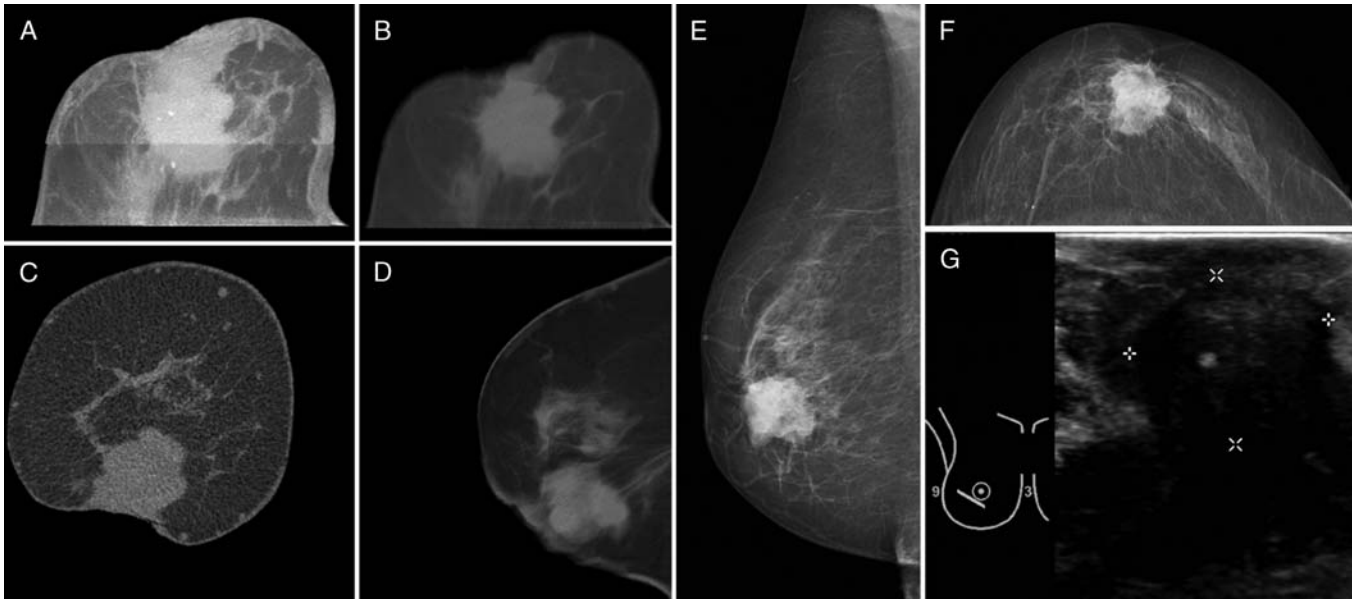

FIGURE 2. A symptomatic 64-year-old patient with no previous examination of the breast and a palpable lump in the right breast. The patient refused mammography. An ultrasound-guided core biopsy was performed, diagnosing an invasive ductal carcinoma. A, B-CT with axial MIP (10 mm) with retro-areolar mass and involvement of the nipple with associated microcalcifications and macrocalcifications. B, B-CT with axial avgIP (10 mm) showing the same mass. The architectural distortion can be better depicted as in the MIP. C, B-CT with coronar reconstruction (150 µm). D, B-CT with sagittal avgIP (10 mm) reconstruction. E, Corresponding mammography in MLO projection showing the mass. F, Corresponding mammography in CC projection showing the mass. G, Ultrasound showing an ill-defined, hypoechoic mass with calcifications a dorsal signal loss.

TABLE 3. Description of the Histologically Proven Malignant Lesions Found in B-CT

	Architectural Distortion	Microcalcifications	Mass	Size in B-CT	Tumor Size	Receptor Status	Tumor Grade
BI-RADS 6	−	−	x	25 mm	34 mm	ER+, P−, Her-2−	1
BI-RADS 6	x	x	x	39 mm	54 mm	ER+, P+, Her-2−	3
BI-RADS 5	−	x	x	9 mm	10 mm	ER+, P+, Her-2−	2
BI-RADS 5	x	x	x	31 mm	*	ER+, P+, Her-2−	2

Description of the histologically proven malignant lesions found in B-CT, rated as BI-RADS 5–6 with distinctive description of architectural distortions, masses, microcalcifications, tumor size in B-CT, and tumor size after histological workup, receptor status (estrogen [ER], progesterone [P], Her-2), of the tumors and tumor grade (grade 1, well differentiated; grade 2, moderately differentiated; grade 3, poorly differentiated, grade 4: undifferentiated).

Lesions in B-CT rated BI-RADS 4 were all B3 lesions.

*The patient was not operated at our hospital; therefore, the final tumor size was not available.

B-CT indicates breast computed tomography; BI-RADS, Breast Imaging and Reporting and Data System.

both readers did not agree on all cases that the breast tissue might be completely included. In a following consensus conversation, one radiologist noted that, even if in the last image only fat tissue is depicted, there might still be glandular tissue following. It could be discussed to add anyhow an additional ultrasound to cover possible not assessed areas. None of the examinations showed any movement artifacts, as stated in a previous study.[7] Still, a slight ring-like artifact could be depicted in each image; it was less prominent compared with the previous study,[7] but still noticeable. Technical difficulties during data acquisition have only occurred 3 times during the examination of 300 women, for example, in 1% of all examination, which demonstrates an already high degree of technical maturity of this new imaging modality.

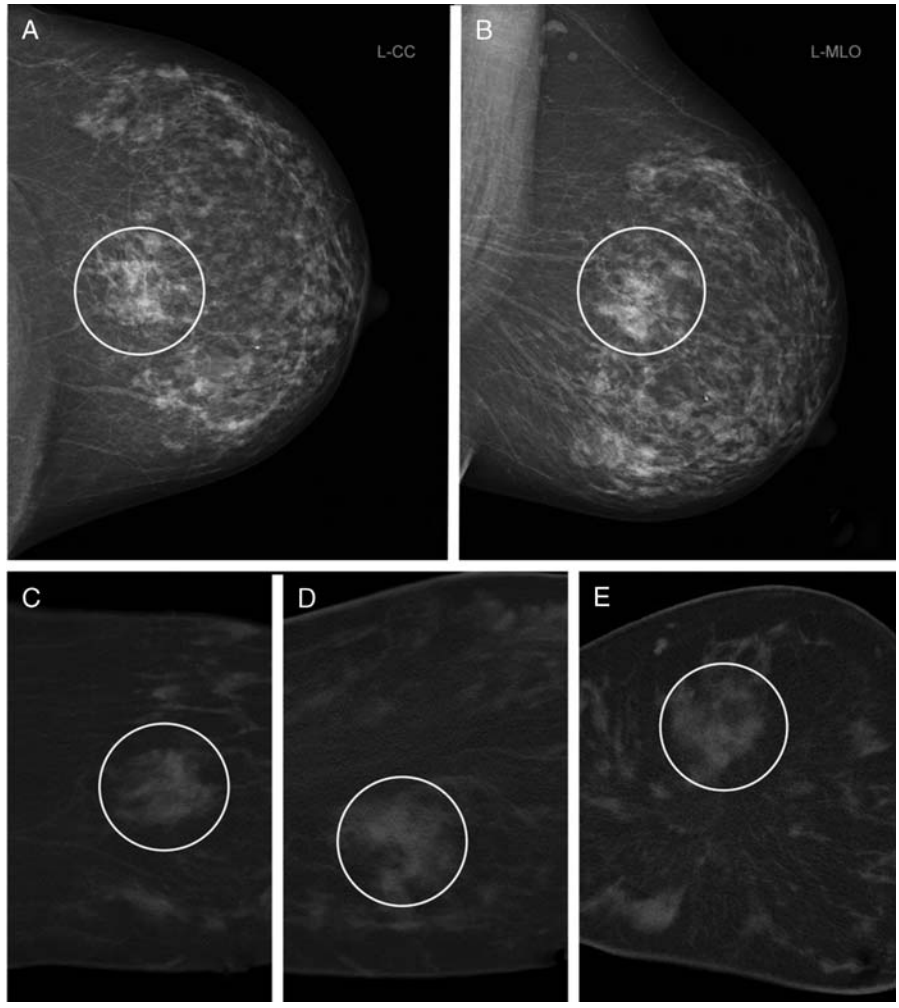

FIGURE 3. A 67-year-old patient with focal prepectoral density in mammography (A and B) with no correlation in ultrasound. In B-CT (C-E), the density presented as normal breast tissue. Nevertheless, an additional MRI was performed, which was normal. C, Axial reconstruction. D, Sagittal reconstruction E, coronar reconstruction, all in avgIP (10 mm).

The radiologists reading the B-CT datasets decided for each patient whether the glandular component was of such high density to potentially mask malignant lesions, and therefore an additional ultrasound examination was required to increase the sensitivity for cancer detection. In this decision making, analog criteria have been applied compared with the ACR mammographic breast density classification. However, from the known advantages of B-CT, it seems clear that in the future, a dedicated B-CT density classification will be required as B-CT images can be reconstructed in different planes facilitating lesion detection, and breast tissue might be less superposed as compared with the overlying tissue in mammography (Fig. 3).

One hundred twenty-four of our patients underwent additional ultrasound only due to dense breast tissue (ACR C and D), resulting in 41.3% of all patients. Compared with previous published numbers, where 32.3% of the patients only had dense breast tissue[11] and additional ultrasound would be recommended, our study shows a higher number of performed ultrasounds. Reasons therefore might be that the technique is still new and the radiologist added more likely an ultrasound or that compared with a screening population, our patients were younger (mean age 56.8 years ±9.9 years) and therefore the breast tissue was more likely to be denser.

Our study has some limitations. First, it is a retrospective study, and as there are still no data comparing the B-CT to mammography, a prospective study comparing the 2 techniques would be desirable. Also, a possible comparison with tomosynthesis, a combination of sets of low-dose projections, giving a limited depth of field but enabling to gain a 3-dimensional impression of the breast, is plausable. Therefore, the comparison between tomosynthesis and the B-CT with the possibility of real multiplanar reconstruction might be very interesting.[12,13] However, patient referred for B-CT to our institution mostly refuse to undergo breast compression during breast imaging. Therefore, such a comparison study between B-CT and conventional mammography might experience a lack of patient compliance. Second, the data were retrieved using the reports written by the resident and only double-checked by a board-certified radiologist. No second separate reading was performed to gain an interreader agreement. Also, the decision on performing an ultrasound was decided by an experienced resident supervised by a board-certified radiologist. Another limitation is that some of the malignant lesions were either clinically already known or found in the ultrasound examination, and therefore, only pseudo-detection rates can be retrieved from our data. Nevertheless, in 300 patients, 9 suspicious lesions were biopsied resulting in 7 malignant lesions (2.3% of the examined patients). Four of the lesions were seen in B-CT (1.3%). Thirty-six lesions were rated BI-RADS 3 (12%). Those numbers are much higher than the number of malignant lesions found in a breast screening program, which detects about 3 to 4 cancers in 1000 patients (0.3%–0.4%).[11] In the current study, we did not focus on the dose aspect. Nevertheless, in a previous study,[4] it was shown that thanks to the photon-counting technology the dose used to perform B-CT imaging is similar to that used to perform mammography. We also consider that this is a very important issue, and further ongoing studies are better at investigating this aspect.

Moreover, the capabilities for cancer detection and characterization using contrast-media injection have not been evaluated.

In conclusion, dedicated spiral CT of the breast using a single photon-counting detector allows for breast cancer detection in isotropic 3-dimensional data compared with mammography, providing a valuable tool for diagnostic breast imaging and breast cancer screening. It can be used as alternative particularly in those patients not otherwise willing to perform mammography because of the breast compression.

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